applied to sagittal baseline and year 1 follow up MR data sets (0.7 mm DESSwe) of 160 knees from 80 participants from the OA initiative with frequent bilateral knee pain (OAI public-use datasets1.2.1 Clinical Data set and 1.B.1 Imaging Data set; 48 women, 32 men; age = 60.6±9.1 yrs.; BMI = 31.1±4.0). The knees were selected based on the site readings in fixed flexion radiographs and were re-read centrally to confirm unilateral medial JSN.73 knees showed mJSN 0, 54 displayed mJSN 1, and 33 mJSN 2/3. The standardized response mean (SRM = mean change/SD of change) of cartilage thickness (ThCtAB) was computed for all subregions of MF as a measure of the sensitivity to change.

Results: In the 160 knees the magnitude and sensitivity to cartilage loss was greatest in regions located at 30º to 75º (Table 1). The region of greatest change, however, varied with JSN: Knees with JSN 0 showed a maximum of −1.5% change (SRM = −0.21) in a region 30º-60º, those JSN 1 a maximum of 3.2% (SRM = −0.35 to −0.37) at 45º-90º, and those with JSN 2/3 a maximum of −9.0% (SRM −0.76) at 15º-45º.

Conclusions: The rate and sensitivity of cartilage loss in the medial femoral condyle (MF) increased with increasing JSN (SRM −0.11 in JSN 0 to −0.85 in JSN 2/3). Interestingly, the location of maximal change in MF varied also with JSN: Painful knees without JSN displayed the greatest changes in a region at 30−60º of MF, whilst those with JSN 1 encountered the greatest changes more posteriorly, and those with JSN2/3 somewhat more anteriorly. Further studies may elucidate the relationship between the pattern of femoral cartilage loss and changes in the posterior horn of the meniscus.

Table 1: Mean change (MC%) for cartilage thickness in the 9 regions of interest of the medial femoral condyle

MC [%]	MF	0º-30º	15º-45º	30º-60º	45º-75º	60º-90º	75º-105º	90º-120º	105º-135º	120º-150º
ALL	−1.6	−2.0	−2.3	−2.9	−2.7	−1.8	−1.0	−0.7	−0.7	−1.1
JSN 0	−0.5	−0.8	−1.1	−1.5	−1.1	−0.2	0.5	0.4	0.0	−0.5
JSN 1	−1.5	−1.1	−1.2	−2.4	−3.2	−2.2	−1.3	−0.7	−0.4	−0.7
JSN 2/3	−5.1	−7.7	−9.0	−8.6	−6.9	−5.7	−4.5	−2.9	−2.4	−2.8

Table 2: SRM for cartilage thickness changes in the 9 regions of interest of the medial femoral condyle (MF)

SRM	MF	0º-30º	15º-45º	30º-60º	45º-75º	60º-90º	75º-105º	90º-120º	105º-135º	120º-150º
ALL	−0.28	−0.19	−0.22	−0.28	−0.33	−0.28	−0.16	−0.11	−0.12	−0.19
JSN 0	−0.11	−0.10	−0.15	−0.21	−0.18	−0.03	0.09	0.08	0.01	−0.11
JSN 2	−0.21	−0.09	−0.09	−0.19	−0.35	−0.37	−0.22	−0.12	−0.07	−0.11
JSN 3	−0.85	−0.60	−0.76	−0.73	−0.59	−0.62	−0.51	−0.42	−0.43	−0.45

394 PRECISION AND SENSITIVITY TO CHANGE FOR DIFFERENT METRICS AND REGIONS OF FEMOROTIBIAL CARTILAGE MORPHOLOGY

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Purpose: To reduce the number of morphological variables of cartilage needed to be reported in longitudinal studies of OA progression, we here investigate the performance (specifically the test-retest precision and the longitudinal sensitivity to change) of different metrics of MR-based cartilage morphology, different computational implementations for calculating these metrics, and different femoral regions of interest.

Methods: In a first component of this study, test-retest acquisitions were acquired in 30 participants (15 healthy, 15 with OA) at one center at 3 Tesla. In a second component, baseline and follow up acquisitions were acquired at baseline and 24 months later in 28 female participants with obesity, symptomatic, and radiographic (K-L grade 3) OA at seven imaging centers (all 3 Tesla). Double oblique (double bull eye) coronal spoiled gradient recalled images at steady state (SPGR) with selective water excitation were acquired. Segmentation of the medial and lateral tibial cartilages; in the femoral cartilage plates two regions of interest (ROIs) were compared: one extending from the trochlear notch to the intercondylar bone bridge (short ROI) and one from the trochlear notch to the 60% slice towards the posterior ends of the femoral condyles (long ROI).

Results: The size of the subchondral bone area for the long femoral ROI was 33.9% larger in the medial and 34.5% larger in the lateral femoral condyle than the short ROI. In addition, the tAB was less variable amongst participants than the short ROI (CV% 11% versus 20% medially and 10% versus 18% laterally). Different cartilage morphology metrics were more precise in the long than in the short femoral ROI, with a coefficients of variation (CV%) for cartilage thickness (ThCtAB) of 2.5% versus 2.8% medially and 2.6% versus 2.7% laterally. Normalized cartilage volume (VCtAB) and mean cartilage thickness (over the entrire subchondral bone area = ThCtAB.Me) were generally more precise and more sensitive to change (SRM −0.29 to −0.62) over two years than cartilage volume (VC), the mean cartilage thickness over the cartilaginous area (ThCcAB), or the maximal cartilage thickness. An implementation computing thickness from the cartilage surface to the bone interface was slightly more sensitive to change in the medial tibia, whereas in the medial femur the computation of thickness from the bone interface to the cartilage surface was slightly superior.

Conclusions: When studying cartilage loss quantitatively with MRI, a long femoral ROI in coronal acquisitions (60% from trochlear notch to posterior end of femoral condyle) shows better performance (higher precision and sensitivity to change) than a short ROI (from the trochlear notch to the interconylar bone bridge). Amongst different cartilage metrics, cartilage volume normalized to total subchondral bone area (VCtAB) and mean cartilage thickness over the entire subchondral bone area (ThCtAB.Me) represent more powerful outcomes than other metrics of cartilage morphology in longitudinal OA studies. Because of slight differences in performance in the tibial and femoral cartilage, an implementation that computes the average of the mean thickness between the articular surface and bone interface, and between the bone interface and articular surfaces, respectively, appears preferable.

395 CLINICAL POTENTIAL OF IN-VIVO BIOCHEMICAL 7.0 TESLA MR – PRELIMINARY RESULTS OF DGEMRIC, ZONAL T2 AND T2* MAPPING OF ARTICULAR CARTILAGE

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Purpose: Ultra-high-field whole body systems (7.0T) have a high potential for future human in-vivo MRI. In musculoskeletal MRI, biochemical imaging of articular cartilage may benefit, in particular. Delayed gadolinium-enhanced MRI of cartilage (dGEMRIC) and T2 mapping have shown potential at 3.0T. In addition, the evaluation of zonal variation provides an indicator of the hyaline nature of cartilage.

Thus, the aim of our study was to show the feasibility of in vivo dGEMRIC, as well as T2 and T2* relaxation measurements, at 7.0T MRI; and to evaluate the potential of T2 and T2* measurements in an initial patient study after matrix-associated autologous chondrocyte transplantation (MACT) in the knee.

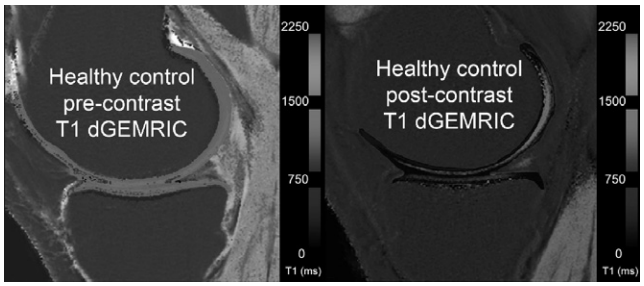
Methods: MRI was performed on a whole-body 7.0 T MR-scanner using a dedicated knee coil. The protocol consisted of an inversion recovery sequence for dGEMRIC (Fig. 1), a multi-echo spin-echo sequence for standard T2 and a GRE sequence for T2*-mapping (Fig. 2) and a morphological PD SPACE sequence. Twelve healthy volunteers (mean age 26.7 years) and four patients (mean age 38.0 years) were enrolled 29.5±15.1 months after MACT. For dGEMRIC, five healthy volunteers were included. ROI analysis was carried out for global (T1dGEMRIC) and additioanlly deep and superficial cartilage aspects (T2 and T2*). Statistical evaluation was performed by analyses of variance.

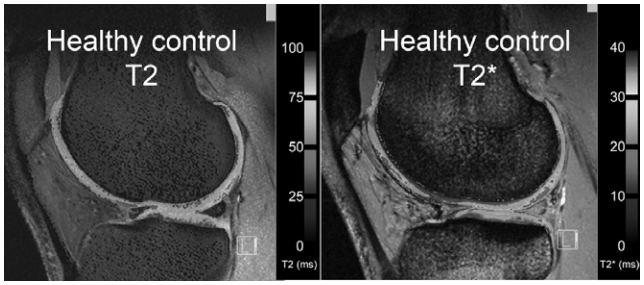
Results: Mean T1 (dGEMRIC) values for healthy volunteers showed slightly different results for femoral (T1(0): 1259 ms; T1(Gd): 683 ms) compared to tibial cartilage (T1(0): 1093 ms; T1(Gd): 769 ms). Global mean T2 relaxation for healthy volunteers showed comparable results for femoral (T2: 56.3 ms; T2*: 19.7 ms) and patellar (T2: 54.6 ms; T2*: 19.6 ms) cartilage, but lower values for tibial cartilage (T2: 43.6 ms; T2*: 16.6 ms). All healthy cartilage sites showed a significant increase from deep to superficial cartilage ($p < 0.001$). Within healthy cartilage sites in MACT patients, adequate values could be found for T2 and T2* with significant stratification. Within cartilage repair tissue, global mean values showed equal values for T2 and T2*. However, zonal assessment showed

only a slight and not significant increase from deep to superficial cartilage (T2: p = 0.174; T2*: p = 0.150).

Conclusions: In vivo T1 dGEMRIC assessment in healthy cartilage, as well as T2 and T2* mapping in healthy and reparative articular cartilage, seems to be possible at 7.0T MRI. For T2 and T2*, zonal variation of articular cartilage could also be evaluated at 7.0T. This zonal assessment of deep and superficial cartilage aspects shows promising results for the differentiation of healthy and affected articular cartilage. In future studies, optimized protocol selection and sophisticated coil technology, together with increased signal at ultra-high-field MRI, may lead to advanced biochemical cartilage imaging.

Concluding, the next step to a potential clinical applicability of ultra-high field MRI in biochemical cartilage evaluation in the follow-up of sophisticated surgical and non-surgical therapies of cartilage defects and osteoarthritis might not be so far away.





396 RELATION OF REGIONAL ARTICULAR CARTILAGE MORPHOMETRY AND MENISCAL POSITION BY MRI TO JSW IN KNEE RADIOGRAPHS

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Purpose: The objective of this analysis was to ascertain the contribution of articular cartilage morphometry and meniscal position on MRI to joint space width (JSW) measured in the Lyon schuss radiograph of the knee, and to specifically identify which subregions of tibial and femoral cartilage and which measures of the meniscus best explain variations in JSW.

Methods: 62 obese women with knee OA and 99 non-obese female controls (mean age 56.6 yrs) were imaged at 7 clinical centers by 3T MRI. Double oblique coronal acquisitions were obtained using water excitation spoiled gradient echo sequences ($1.0 \times 0.31 \times 0.31\ mm^3$ resolution). Segmentation of femoro-tibial cartilage morphology was performed using Chondrometrics GmbH software. Meniscal position (subluxation and % coverage of the medial tibial plateau) was measured in sagittal and coronal planes (EFilm software). Minimum medial joint space width (mJSW) was measured by computer in the Lyon Schuss knee radiograph; Kellgren and Lawrence grades (KLG) were assigned on standing anteroposterior knee films. The relative contribution of regional cartilage thickness and meniscal position to mJSW was assessed initially in univariate models and subsequently with multivariable modelling.

Results: 65% of the variation in mJSW was explained by KLG, regional cartilage thickness measures (central MT + central MF + external MT + posterior MT + internal MT) and meniscal coverage. Of these measures the medial tibia cartilage thickness measures (in particular central, external, and to a lesser extent the internal and posterior subregions) and central region of the weight-bearing femoral condyle (ccMF) play a consistent and small role in variations in mJSW observed across all KLG. This however explains only approximately one third of the mean difference in mJSW that exists between KLG2 subjects and those without OA (KLG0). In contrast ccMF and the addition of percent meniscal coverage to this model explains the remaining differences in mean mJSW found between those subjects with definite joint space narrowing (KLG3) and those without OA.

Table 1: Factors associated with mJoint Space Width: Multivariable analysis with stepwise progression

Model	R^2 for model	Compared against	p value	Model selected
KLG Only	0.2675	Mean	0.0000	KLG Only
KLG + Compartment	0.5796	KLG Only	0.0000	KLG + Compartment
KLG + Plate	0.5095	KLG Only	0.0000	KLG + Plate
KLG + Region	0.6115	KLG Only	0.0000	KLG + Region
KLG + Meniscus	0.3071	KLG Only	0.0277	KLG + Meniscus
KLG + Region + Meniscus	0.6507	KLG + Region	0.0013	KLG + Region + Meniscus
KLG + Region + Meniscus + Plate	0.6528	KLG + Region + Meniscus	0.6580	KLG + Region + Meniscus
KLG + Region + Meniscus + Lateral Compartments	0.6889	KLG + Region + Meniscus	0.2488	KLG + Region + Meniscus
Core Model	0.6453	KLG + Region + Meniscus	0.8077	Core Model

Core Model = KLG + cMT + ccMF + pct.cover + eMT + pMT + iMT

Conclusions: The variation in radiographic mJSW is best described by 5 regional cartilage thickness measures (central MT + central MF + external MT + posterior MT + internal MT) and percent meniscal coverage. The magnitude of each measures contribution differs according to radiographic severity with more variability explained by cartilage thickness of ccMF cartilage thickness and percent meniscal coverage with more severe disease. ~35% of the LS JSW is not our model with some possible explanation(s) being (a) the differences between the tibiofemoral *contact sites* in a LS view taken in about 20 degrees of flexion and an extended knee MRI, and (b) the difference in cartilage thickness with compression on *weightbearing* in the LS view but not in acquiring the MRI measurements.

397 CARTILAGE LOSS OCCURS IN THE SAME SUBREGIONS AS SUBCHONDRAL BONE ATTRITION: THE MOST STUDY

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Purpose: Although subchondral bone is thought to play an important role in OA progression, subchondral bone attrition (SBA) has been little studied. Contrary to previous thinking that it is a late finding on x-rays, SBA can be seen in early OA by MRI, but the significance of this is unknown. For example, it is unknown whether subchondral bone attrition is related to overlying cartilage defects. We therefore evaluated the association of SBA with cartilage loss over time occurring within the same subregion of the knee.

Methods: The Multicenter Osteoarthritis (MOST) Study is a NIH-funded longitudinal observational study of individuals who have or are at high risk for knee OA. At baseline and 30-month follow-up, participants had knee MRIs performed (1.0T; axial and sagittal proton density fat suppressed and coronal STIR sequences). MRIs were graded using WORMS in 5 subregions within each of the medial and lateral tibiofemoral (TF) compartments (central, posterior femur; anterior, central, posterior tibia) for cartilage (0−6) and SBA (0−3). Cartilage loss within each subregion was defined as any worsening of WORMS score (except that a score of 0 had to increase to at least a score of 2) between the 0 and 30-month MRIs. We conducted analyses within a knee (one knee per person) to eliminate between-person confounding, using an M:N matched case-control approach in which the 10 subregions of a person's knee (TF joint) forms a matched set. Cases within a given knee were defined as the subregions in that knee with cartilage loss (increase in score by $\geqslant 1$) while controls were the subregions in that same knee without cartilage defects (score = 0). Eligible knees had to have both case and control subregions. We evaluated the association of cartilage loss over time with the baseline presence of SBA (score $\geqslant 1$) in the same subregion within that knee using conditional logistic regression, and repeated analyses in a compartment-specific manner. We also evaluated these associations using a higher